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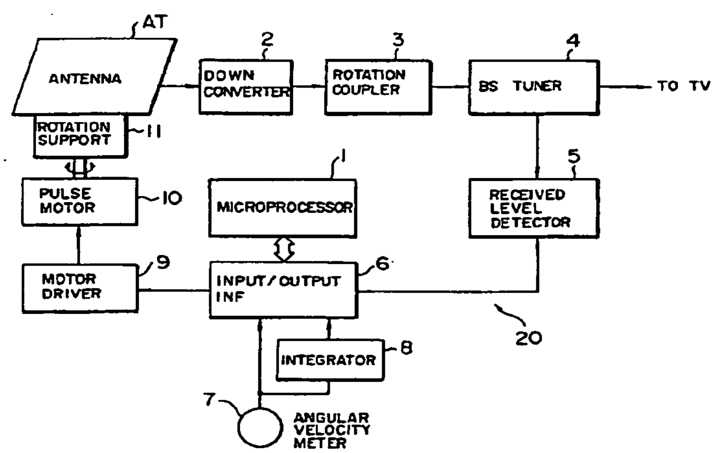

(57) Abstract

The tracking control apparatus (20) for a mobile-type satellite-broadcast receiving antenna which is installed on mobile body detects the level of a radio wave received by the antenna (AT), and repeatedly rotating, on the basis of this detected received signal level, the antenna over a certain angle at higher rotation velocity as increment of the received signal level per unit angle associated with the preceding rotation becomes larger, thereby controlling the rotation angle of the antenna (100). Within a period in which the received signal level is larger than a threshold, the rotation angle of the antenna is held at the current value and the received signal level is monitored (200). When the received signal level is reduced to be less than the threshold, the angular velocity of the mobile body and its integrated value are detected (7, 8), and if either one of the values is significant, the angular error in the turning operation of the mobile body is regarded as having increased, and the antenna is controlled for its rotation angle (100). If both the values are not significant, the increase of the angular error is considered as having been suddenly caused by an obstacle, and the control apparatus waits for the received signal level to be restored to a proper value (300).

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DESCRIPTION

SATELLITE-BROADCAST RECEIVING MOBILE ANTENNA APPARATUS

TECHNICAL FIELD

This invention relates to mobile antenna apparatus for use in receiving satellite broadcasts, and particularly to a satellite-broadcast receiving mobile antenna apparatus with an improvement in the automatic tracking system rendered small in size and reduced in cost.

BACKGROUND ART

As satellite broadcasting receivers have been widely used in recent years, mobile antennas have been developed which are installed in various mobile means such as cars and vessels in order to receive satellite broadcasts. In the future, it will be supposed to receive radio waves not only from stationary satellites like broadcasting satellites but also from moving satellites or to take services including communications (transmission and reception) with satellites in addition to receiving broadcasts. In this kind of mobile antenna apparatus, particularly in the satellite-broadcast receiving antenna apparatus mounted on a vehicle, it is absolutely necessary to provide an automatic tracking mechanism for always directing the antenna body toward the associated satellite even if the satellite is stationary as well as moving because the orientation of

the moving car may change every moment.

This automatic tracking mechanism is materialized by a combination of an azimuth control apparatus for controlling the horizontal component (hereinafter, referred to as "tracking azimuth") of the direction of the antenna body and an elevation control apparatus for controlling the elevation angle of the antenna body. This automatic tracking mechanism takes a considerable part of cost of the whole satellite-broadcast receiving system including electric circuit components such as a converter and a tuner, and increases the installation height and area of the antenna apparatus. Therefore, how much this mechanism can be simplified is one of the important technical subjects.

Since the tracking azimuth of the antenna body is necessary to be controlled over 360 degrees as the antenna-installed vehicle moves, it can be considered practical that the tracking azimuth is controlled by a mechanically rotating mechanism. The elevation angle of the antenna body, as contrasted with the above, may be sufficiently controlled by changing in rather limited range in accordance with the latitude of the area in which the vehicle is moving and with the road slope variations of about ± 5 degrees along which the vehicle is moving particularly when the antenna is directed toward a stationary satellite like a broadcasting satellite. Thus, the control range for the elevation angle is limited to a relatively small value.

Accordingly, the satellite-broadcast receiving mobile antenna apparatuses have been deviced to employ a single-axis tracking system in which only the tracking azimuth is controlled with the directivity of the antenna in the elevation being previously set to be wide and to employ a system in which the elevation is discretely and coarsely controlled, thereby achieving the miniaturization and cost-reduction of the whole receiving system. The tracking azimuth control apparatus is maintained substantially independent of the elevation control apparatus whatever elevation control is made. A relatively important tracking azimuth control will be described below.

One of the tracking control apparatus for the mobile-type satellite-broadcast receiving antenna apparatus, or a phase-difference detecting system, is known as disclosed in the Japanese Patent Application No. 3-350103 which the same assignee of this invention previously filed. In this phase-difference detecting system, some divided parts of a satellite-broadcast receiving antenna are arranged in a certain direction having a spacing from each other so that an error between the direction of an incoming radio wave and the antenna parts arranging direction, namely a tracking error of the whole antenna can be detected from the phase difference between the radio waves received by the respective divided parts of the antenna. This tracking control apparatus has many advantages, but has a problem

of high cost.

Another tracking control apparatus rotates the antenna until the received signal level becomes the maximum. This type of tracking control apparatus is known as an auto-threshold system as disclosed in Japanese Patent Application No. 4-176992 or as a vibration system as disclosed in Japanese Patent Application No. 4-60479. However, the tracking mechanism of the auto-threshold system or vibration system is too low in tracking ability to respond to rapid turning of car at left or right turns.

A direction-sensor system can be considered which, in principle, uses a direction sensor to detect the orientation of mobile means in which the associated satellite-broadcast receiving antenna is installed, calculates a tracking azimuth at which the antenna is directed on the basis of the detected orientation of the mobile means, and controls the antenna direction according to the calculated result. In this direction-sensor system, however, the tracking azimuth to be calculated depends on the longitude and latitude of the spot at which the mobile means exists. Therefore, there are problems that a positioning system such as a GPS receiver is also necessary for detecting the longitude and latitude and that the longitude and latitude must be roughly set and changed by human hands, this operation is troublesome.

One of the reasons for the difficulty in the

tracking control of such mobile antenna is that a high tracking ability is required in order to respond to a rapid change of direction which, as mentioned above, occurs when the mobile means turns left or right, such a large angle change of about 90 degrees, in a relatively short period of time.

Another reason for the difficulty in the tracking control of the mobile antenna is that as the mobile means moves the radio waves from the satellite to the mobile means is frequently blocked off in short periods of time by electric light poles or telephone poles, buildings, bridges, trees and mountains along the road. Under this situation, the received signal level is suddenly reduced though the reduction lasts only a short time, thus disabling the tracking function. If this sudden reduction of received signal level occurs just instantaneously due to an obstacle, it is useless to continue the tracking operation and the received signal level will be immediately restored to the original value. Therefore, when the sudden reduction of received signal level derived from an obstacle, it is rational to wait for the received signal level to be restored to the original value without changing the direction of the antenna.

However, it is uncertain whether this sudden reduction of received signal level has derived from an obstacle or from the rapid turning of the vehicle which leads to a rapid increase of tracking error. When a

sudden reduction due to the rapid turning of the vehicle is mistaken as it had occurred due to an obstacle, the received signal level is waited to be restored to the original value under that condition. Thus, the start of necessary tracking operation is delayed by this waiting time. On the contrary, when a sudden reduction due to an obstacle is mistaken as it had occurred due to the rapid turning of the vehicle, unnecessary tracking control is started and the direction of the antenna may be changed away from the correct direction by this unnecessary tracking operation. The time in which the received signal level is reduced by an obstacle greatly depends on the size of the obstacle and the speed of the vehicle. This also makes difficult to obtain proper tracking control, resulting in reduction of reception efficiency.

DISCLOSURE OF INVENTION

It is an object of the invention to provide a tracking control apparatus having a high tracking ability which is responsive to a rapid change of azimuth angle.

It is another object of the invention to provide a tracking control apparatus which is capable of immediately discriminating whether the sudden reduction of received signal level is caused by an obstacle or by the rapid turning of the mobile means and starting to control in accordance with the situation, thereby

improving the tracking ability at the time of rapid turning and the stability of control at the time of sudden reduction.

The tracking control apparatus for mobile-type satellite-broadcast receiving antenna which is installed on mobile means, according to this invention, has tracking control executing means for detecting the level of a radio wave received by the antenna, the angular velocity of the mobile means and the integrated value of the angular velocity and controlling the rotation angle of the antenna on the basis of the detected received signal level, the angular velocity and the integrated value.

This tracking control executing means has differentiation control executing means for repeatedly rotating the antenna over a certain angle at a higher rotation velocity, when the increment of the received signal level per unit angle associated with the preceding rotation is larger.

This tracking control executing means may further have hold control executing means for comparing the detected signal level with a predetermined threshold Lt and, if this received signal level exceeds the threshold Lt, repeating the detection of a most-recent value of the received signal level and the comparison with the threshold Lt while holding the rotation angle of the antenna at the current value. If the angular velocity or its integrated value is larger than a

predetermined threshold when the detected most-recent received signal level is reduced to be less than the threshold Lt, the hold control executing means immediately causes the differentiation control execution means to start. If either one of the detected angular velocity and its integrated value is less than the threshold, the hold control executing means causes the wait control executing means to start waiting over a certain period for the received signal level to be restored to a proper value.

Another tracking control apparatus of the invention for a mobile-type satellite-broadcast receiving antenna which is installed on mobile means is constructed so that each inherent effect can be achieved by a part of the above various control executing means.

This tracking control apparatus has turning-angle detecting means for detecting the turning angle of the mobile means by integrating the horizontal component of the detected angular velocity and satellite searching means for detecting an amount of change of the turning angle detected by the turning angle detecting means from a value detected just before a tracking-off when any tracking-off occurs in which the received signal level is reduced to be less than a certain threshold, correcting the current tracking azimuth on the basis of this change amount of turning angle, and changing the tracking azimuth around this corrected value within a range which is increased with lapse of time, thereby

making a search for the satellite.

The relation between the received signal level of the antenna and the angular error is approximately according to the Gaussian distribution curve, namely the amount of change (or differentiation) of the received signal level per unit angle gets greater when the angular error gets larger. Therefore, the differentiation control executing means decides that the angular error becomes larger when the amount of differentiation goes larger, then rotates the antenna by steps having a certain angle at a high rotation velocity. Thus, since the amount of differentiation and the rotation velocity are reduced stepwise with the decrease of the angular error as the antenna is rotated, the rotation angle can be prevented from being excessively passed over the target, or from overshooting. As a result, the tracking ability is enhanced enough to easily immediately deal with the sudden reduction of the received signal level due to the rapid turning of the vehicle. The amount of differentiation is rather decreased in the region where the angular error is extremely large. In this region, however, the received signal level is so reduced that the differentiation control itself may be eliminated, and thus such region is not necessary to be considered.

In addition, according to the hold control which is executed in addition to the differentiation control, if the angular velocity or its integrated value detected when a newly detected value of the received

signal level is less than the threshold is larger than a certain threshold, the reduction of the received signal level may be regarded as caused by the reduction of the tracking precision derived from movement of the vehicle. In this case, the differentiation control is immediately started without waiting for the received signal level to be restored to a proper value. On the other hand, if the angular velocity and its integrated value are both less than their threshold, the reduction of the received signal level is considered as having suddenly caused by an obstacle. In this case, the wait control is started by which the received signal level is waited over a certain period to be restored to a proper value. Thus, by using not only the received signal level but also the angular velocity or its integrated value which indicate the movement of the vehicle, it is possible to immediately decide whether the reduction of the received signal level is suddenly caused by an obstacle or by the increase of the tracking error due to the turn of the mobile means and to select proper control means, thus greatly improving the tracking ability.

Moreover, according to the tracking control apparatus of the invention, which has the turning-angle detecting means and the satellite searching means, both the tracking azimuth of the antenna body and the orientation of the mobile means may be used with their relative values. In other words, the tracking azimuth of the antenna may always be expressed by an angle

measured in the clockwise direction or counter-clockwise direction relative to the current value as a reference value (zero). Also, the orientation of the mobile means is expressed by the integrated value of the detected angular velocity as a relative value. When a tracking-off state occurs, the amount of change, just before the tracking-off, of the turning angle detected by the turning-angle detecting means is detected.

In other words, if the tracking-off is caused by the fact that the mobile means has turned by an angle $\theta°$ in the clockwise direction, the amount $\theta°$ of change of the integrated value of the angular velocity developed just before this tracking-off is detected. The current tracking azimuth of the antenna body is corrected in the counter-clockwise direction according to the detected amount of change of the integrated value, and thereby the center value of the range of the tracking azimuth can be estimated. Then, the antenna is rotated around this center value over a range which is increased with lapse of time, thereby searching for the satellite. If the search for the satellite becomes successful at the initial time when the range stays small, the consumption power can be reduced or saved.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a block diagram of one embodiment of the tracking control apparatus of the invention, showing together with the associated satellite-broadcast

receiving antenna being controlled.

Fig. 2 is a diagram for explaining the relation of the angular error of the antenna to the received signal level and the differentiated value of the received signal level and the relation between the received signal level and various thresholds.

Fig. 3 is a flowchart for one example of the differentiation control which is executed by the tracking control apparatus of the embodiment.

Fig. 4 a flowchart for one example of the hold control which is executed by the tracking control apparatus of the embodiment.

Fig. 5 is a flowchart for one example of the wait control which is executed by the tracking control apparatus of the embodiment.

Fig. 6 is a flowchart for one example of the sweeping procedure which is executed by the tracking control apparatus of the embodiment.

Fig. 7 is a diagram for explaining the relation between the angle of turn of the mobile means and the tracking azimuth of the antenna.

Fig. 8 is a waveform diagram of the angular velocity developed as the mobile means turns, integrated value of the angular velocity, center value of tracking azimuth, sweep angle range and sweep velocity with respect to time.

Fig. 9 is a flowchart for search processing which is executed by the mobile-type satellite-broadcast

receiving antenna apparatus of another embodiment of the invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Fig. 1 is a block diagram of the tracking control apparatus for mobile-type satellite-broadcast receiving antenna of one embodiment of the invention, showing together with a satellite-broadcast receiving antenna AT being controlled. Referring to Fig. 1, there are shown a microprocessor 1, a down converter 2, a rotation coupler 3, a tuner 4, a received signal level detector 5, an input/output interface circuit 6 having an A/D converter and a D/A converter, an angular velocity meter 7, an integrator 8 for integrating the angular velocity detected by the angular velocity meter 7, a motor driver 9, a pulse motor 10 and a rotation support mechanism 11.

A television signal of 12 GHz band transmitted from a broadcasting satellite and received by the satellite-broadcast receiving antenna AT is converted into a television signal of one-GHz band intermediate frequency by the down converter 2. The converted intermediate-frequency signal is fed through the rotation coupler 3 to the tuner 4, where it is demodulated into a video signal and an audio signal, which are then supplied to the associated television receiver. The received signal level detector 5 detects the level of the signal received by the antenna AT (, or

the received signal level) on the basis of the noise level produced from the automatic gain control amplifier within the tuner 4. In other words, when the received signal level is reduced, the gain of the automatic gain control amplifier is increased and accordingly the noise level is increased. The received signal level is detected on the basis of the increase or decrease of the noise level, converted into a digital signal by the input/output interface circuit 6 and fed to the microprocessor 1.

The angular velocity meter 7 is mounted at a proper position in the vehicle which has installed therein the antenna AT and the tracking control apparatus of this embodiment. This angular velocity meter detects the angular velocity of the vehicle occurring when the vehicle changes the course (turns). The angular velocity meter 7 may be any one sold in a market, for example, "GYROSTAR" manufactured by Murata Seisakusho Inc. The detected angular velocity contains the polarity indicating the turning direction of the vehicle and it is fed to and held in the input/output interface circuit 6. The detected angular velocity is also fed to the integrator 8 where it is integrated. The integrated angular velocity is supplied to the input/output interface circuit 6 and held therein. The held values are updated each time the output from the angular velocity meter 7 changes at a certain sampling period, and transferred from the input/output interface

circuit 6 to the microprocessor 1 in accordance with the demand from the microprocessor 1. The received signal level detected by the received signal level detector 5 is also processed in the same way. In place of the integrator 8, the microprocessor 1 may of course integrate the angular velocity.

Hereinafter, in place of saying that the angular velocity or received signal level from the input/output interface circuit 6 is received by the microprocessor 1, it will be cited that the angular velocity or received signal level is detected by the microprocessor 1. The microprocessor 1 determines the rotation direction and rotation angle for the tracking control on the basis of the detected received signal level, the angular velocity and the integrated value of the angular velocity. A train of pulses the number of which corresponds to the rotation angle is supplied from the microprocessor 1 through the input/output interface circuit 6 and motor driver 8 to the pulse motor 9. The rotation direction and rotation velocity will be described in detail later. The rotating shaft of the pulse motor 10 is coupled to the antenna AT through the support mechanism 11 for rotatably supporting the antenna AT, thus controlling the direction angle of the antenna AT.

Some thresholds for the received signal level are defined in order for various kinds of control to be executed in accordance with the received signal level

changing every moment. These thresholds are defined as ratios (or relative values) to a peak value Lp as shown in Fig. 2. The peak value Lp is the maximum value of the most recently received signal levels detected by the microprocessor. Each time a most-recently received signal level is detected as exceeding a threshold Lo which is a certain magnifying power larger than the peak value (for example, 110% of the peak value), the peak value is updated to be replaced by this larger received signal level. The reason for providing a hysteresis of 10% for update of the peak value is to prevent from wasteful processing steps for frequently updating the peak value when the received signal level changes in a short time.

A threshold Lt is slightly lower than the peak value Lp (for example, 93%). As long as the received signal level exceeds this threshold Lt, antenna rotation is not rendered in tracking operation. A threshold Lb is considerably lower than the peak value (for example, 20%). When the received signal level is reduced to be lower than this threshold Lb, it is regarded as a large angular error occurs. In this case, the microprocessor 1 starts to execute a sweeping procedure for searching the direction of the satellite by changing the azimuth of the antenna up to 360 degrees. A threshold Lm is an intermediate value between the peak value Lp and the threshold Lb (for example, 50%). The meaning of this threshold Lm will be mentioned later.

The differentiation control which is executed by the microprocessor will be described with reference to the flowchart of Fig. 3. This differentiation control is started chiefly in the following cases:

(1) When a received signal level larger than the threshold Lb is detected as a result of executing the sweeping procedure.

(2) When the received signal level is reduced to be lower than the threshold Lt of about 93% of the peak value, and when an angular velocity or the integrated value of the angular velocity of significant value larger than a threshold is detected, thus it being decided that a considerable angular error has occurred as the vehicle turns.

The microprocessor 1, when starting the execution of the differentiation control, first decides whether the direction in which the antenna rotates is definite or not (step 11). When the sweeping procedure had been executed as the tracking control immediately before this differentiation control, the rotation direction is already decided in the sweeping procedure as that is the same direction in which the received signal level was increased to be higher than the value Lb in the sweeping procedure. If the differentiation control is started when the angular velocity or the integrated value of the angular velocity has exceeded a significant value, the antenna may be rotated in the opposite direction to the turning direction of the

vehicle indicated by the sign of the value, thus the direction in which the antenna is to be rotated is decided. However, since the sign of the integrated value of the angular velocity may be indefinite compared with that of the angular velocity, the direction in which the antenna is to be rotated is confirmed only in that case (step 12). In other words, the microprocessor first rotates the antenna by a certain angle in the direction predicted from the sign of the integrated value of the angular velocity. If the received signal level increases as the antenna is rotated, this direction is decided as a correct direction in which the antenna is to be rotated. If the received signal level decreases, the opposite direction is decided as a correct direction in which the antenna is to be rotated.

When the rotation direction is completely fixed, the microprocessor 1 sets an initial value Vo for the rotation velocity V of the antenna (step 13), and causes the antenna to rotate by a predetermined angle $\Delta\theta$ in the fixed direction at this rotation velocity Vo (step 14). Then, the microprocessor detects an increment ΔL, or the difference between a most-recently received signal level L and the preceding received signal level before the rotation for this received signal level L (step 15). Thereafter, the microprocessor decides whether the detected most-recently received signal level exceeds the threshold Lb or not (step 16). If the answer is yes, the program advances to the next

step 17. If the answer is no, the program advances to the sweeping procedure. At step 17, the microprocessor 1 changes the rotation velocity V of the antenna to a value which is proportional to ΔL.

The microprocessor 1 newly detects the received signal level L and decides whether the received signal level L exceeds the threshold Lt or not (step 18). If the decision is no, it is decided that the antenna is not directed toward the satellite, and thus the program goes back to step 14, where the antenna is further rotated by a predetermined angle Δθ at the fixed velocity V. In this embodiment, the predetermined Δθ is set according to the number of pulses fed to the pulse motor, and the rotation velocity is changed by altering the time interval between the pulses fed to the pulse motor. Thus, the microprocessor changes the rotation velocity to a value proportional to the increment of the received signal level detected upon the preceding rotation and causes the antenna to rotate by the angel Δθ each time the rotation velocity is changed until the most-recently received signal level exceeds the threshold Lt (step 14 to step 18).

After detecting that the most-recently received signal level has exceeded the threshold Lt at step 18, the microprocessor 1 executes the next step 19, where it is decided whether the set rotation velocity V is smaller than a certain threshold Vth. If the decision is no, it is decided that the antenna is not

precisely directed toward the satellite yet and thus the program goes back to step 14. The microprocessor repeats the control from step 14 to step 19 until the received signal level L exceeds the threshold Lt and until the rotation velocity V decreases below the threshold Vth. When the most-recently received signal level is close enough to the peak value Lp, the decision result of step 19 becomes yes. In this case, the microprocessor stops the execution of the differentiation control and starts the execution of the hold control.

The hold control which the microprocessor 1 executes will be described with reference to the flowchart of Fig. 4. The microprocessor first sets a new value of the peak value Lp to the received signal level detected just before the start of this hold control, and calculates to renew the thresholds Lt, Lb, Lm and Lo relative to the peak value (step 21). Then, the microprocessor detects a most-recent value of the received signal level L (step 22) and compares it with the threshold Lt (step 23). If the received signal level L is larger than the threshold Lt, the microprocessor executes step 24 to compare the received signal level L with the threshold Lo. If the received signal level L is smaller than the threshold Lo, the microprocessor goes back to step 22 and again executes the steps 22 to 24.

In other words, as long as the receiving condition is kept stable in which the current received

signal level is maintained larger than the threshold Lt, the steps 22 to 24 are repeatedly executed. This repeating process may be executed in an asynchronous state in which a successive processing step is continuously executed after a preceding step or in a synchronous state in which certain waiting times are provided at appropriate locations so that the processing steps are repeated with a constant period. During the execution of the hold control, the rotation angle of the antenna is kept at the value that is set just before the execution.

If the most-recently received signal level L is decided to have exceeded the threshold Lo at step 24, the program goes back to step 21, where the microprocessor 1 uses this received signal level as the new peak value Lp and again calculates the thresholds Lt, Lb, Lm and Lo with relation to this new peak value. If the new received signal level L is decided to be smaller than the threshold Lt at step 23, the microprocessor detects the angular velocity and decides whether it exceeds the threshold or not (step 25). If the detected angular velocity is decided not to have exceeded the threshold yet, the microprocessor detects its integrated value and decides whether it exceeds the threshold or not (step 26). The integrated value of the angular velocity is introduced because, when the vehicle is running along an expressway with a moderate large curve, the integrated value over a long time becomes consider-

ably large though the deviation of the angular velocity due to the tracking error is small. In that case, the angular velocity itself is not so large as to exceed the threshold but its integrated value exceeds a significant value.

If the received signal level L is lower than the threshold Lt, the microprocessor 1 executes steps 25 and 26 where it is decided whether the angular velocity or its integrated value exceeds the corresponding threshold or not. At this time, if either one of the angular velocity or its integrated value is decided to have exceeded the corresponding threshold, the tracking error is regarded as having been increased as the vehicle turns. Thus, the differentiation control is started to execute as already described with reference to Fig. 3. If the received signal level L is lower than the threshold Lt, and if, at steps 25 and 26, either one of the angular velocity or its integrated value is decided not to have exceeded the corresponding threshold yet, the microprocessor regards the reduction of the received signal level as having been suddenly caused by an obstacle, and starts the execution of the wait control.

The wait control to be executed by the microprocessor 1 will be described with reference to the flowchart of Fig. 5. The wait control is carried out fundamentally for monitoring that the received signal level is restored to a larger value than the threshold

Lt or that the angular velocity is increased to a larger value than the threshold, and causing the antenna to be placed under the control corresponding to the result of the monitoring. In other words, if the received signal level is restored to a larger value than the threshold Lt, the reduction of the received signal level is regarded as having been temporarily (suddenly) caused by an obstacle and the hold control is immediately started. If the angular velocity is detected to have been increased to a larger value than the threshold within this waiting period, the reduction of the received signal level is regarded as having been caused not only by an obstacle but also an angular error occurring as the vehicle turns, and the differentiation control is brought about. Such cases may occur, for example, when a composite change has occurred in which an angular error occurring as the vehicle turns is caused immediately after the instantaneous reduction of the received signal level due to an obstacle.

This wait control is fundamentally divided into the first portion (first wait control) in which the above monitoring of the change of state is repeated with a short period and the second portion (second wait control) in which the monitoring of the change of state is repeated with a long period. For example, the whole period for the execution of the wait control is set to about two seconds. The period for the first portion is set to about 0.3 second and that for the second portion

to about 1.7 second. The period for repeating the monitoring of the presence or absence of the change of state is set to about 10 milliseconds in the first portion and to about 100 milliseconds in the second portion.

When the wait control is started to execute, the microprocessor 1 first makes initialization for a time T which is progressively changed at a constant speed by a counter in order to control the time lapse and for a status flag F into zero (step 31). Then, the microprocessor 1 decides whether the acceleration becomes so significant as to exceed a certain threshold or not (step 32). If the acceleration is detected not to exceed the threshold, a new received signal level L is detected (step 33) and it is decided whether this received signal level is larger than the threshold Lt or not (step 34).

If the received signal level L is not larger than the threshold Lt, the microprocessor 1 decides whether or not the lapse time T from the start of the execution of the wait control is larger than a predetermined time Tm for determining the first portion (first wait control) of the wait control (step 35). If the decision result is no, the program goes back to step 32, and the microprocessor repeats the steps 32 to step 35. The repeating of those steps may be executed in the asynchronous way in which the successive processes are continuously performed after the preceding processes

without delay or in the synchronous way in which waiting times are provided at appropriate locations so that the processes are carried out with a constant period (for example, 10 millisecond) as shown in Fig. 5.

If the acceleration is detected to become significant during the above repeating process (step 32), the microprocessor regards the reduction of the received signal level as having been caused not only by an obstacle but also by the turn of the vehicle, and immediately starts the execution of the differentiation control. On the contrary, if the received signal level is detected to have exceeded the threshold Lt during the above repeating process (step 34), the reduction of the received signal level is regarded as having been suddenly caused by an obstacle, and the hold control is immediately started by the microprocessor 1.

If it is detected that the lapse time T has exceeded the certain time Tm during the repeating process (step 35), the microprocessor 1 starts the execution of the second wait control which starts with step 36. After the execution of the second wait control, the microprocessor 1 decides whether the acceleration is detected to be larger than the threshold (step 36). If the acceleration is not so significant as to exceed the threshold, a new received signal level L is detected (step 37), and it is decided whether the new received signal level is larger than the threshold Lt (step 38). If the received signal level L is not larger

than the threshold Lt, the microprocessor 1 decides whether or not the received signal level L exceeds the threshold Lm (step 39). If the received signal level L is not larger than the threshold Lm, the microprocessor sets the status flag F to "0" (step 40) and decides whether the lapse time T from the execution of this wait control exceeds a certain value Tw which defines the period in which the wait control is executed (step 41).

If the lapse time T from the beginning of the execution of the wait control is smaller than the value Tw, the microprocessor 1 executes the step 44 where a waiting time is determined relative to the repeating period To. After the step 44, the program goes back to the step 36 and the steps 36 to 44 are repeated. If the acceleration is decided to become so significant as to exceed the threshold during the repeating process in the same way as in the first wait control (step 36), the microprocessor regards the reduction of the received signal level as having been caused not only by an obstacle but also by the turn of the vehicle, and immediately starts the execution of the differentiation control. If the received signal level is decided to have exceeded the threshold Lt during the repeating process (step 38), the microprocessor considers the reduction of the received signal level as having been suddenly caused by an obstacle, and immediately starts the execution of the hold control.

If at step 41 it is decided that the lapse

time T from the start of execution of the wait control has exceeded the value Tw, the microprocessor 1 considers the sudden reduction of the received signal level as having not been caused by an obstacle, ends the execution of the wait control, and starts to execute the sweeping procedure in order to search for the satellite up to an angle range of 360 degrees.

If it is decided that the new received signal level L is smaller than the threshold Lt but larger than the threshold Lm (step 39), the microprocessor 1 examines if the status flag F is 1 (step 42). If the status flag F is zero, the microprocessor 1 changes it to 1 (step 43), and goes through the step 44 for the waiting state and goes back to step 36. After then, when detecting that the status flag F is 1 at step 42, the microprocessor 1 ends this wait control and starts the differentiation control. The reason why the status flag F is employed is to enhance the tracking ability by immediately executing the differentiation control without executing the sweeping procedure because the tracking error may be regarded not so large when the received signal level L does not exceed the threshold Lt but exceeds the threshold Lm twice successively.

The sweeping procedure which the microprocessor 1 executes will be described with reference to the flowchart of Fig. 6. This sweeping procedure is used to search for the direction of the satellite when the received signal level L does not exceed even the

threshold Lm which is a considerably low value relative to the peak value (for example, 50%), or when a large tracking error continuously occurs over a certain period, or in an extreme case when it is decided that the satellite has been tracked-off or when the initial tracking operation starts immediately after the power supply.

When starting to execute the sweeping procedure, the microprocessor 1 causes the antenna to rotate left and right repeatedly about the present rotation angle up to a maximum range of ± 5 degrees, detects the received signal level during the antenna rotation and decides whether the received signal level exceeds the threshold Lb or not (step 51). If the received signal level is smaller than the threshold Lb, the microprocessor 1 executes the next step 52, where the received signal level is detected while the antenna is being caused to rotate left and right repeatedly about the current rotation angle up to a maximum range of ± 20 degrees and it is decided whether the received signal level exceeds the threshold Lb. Thereafter, similarly the microprocessor stepwise changes the rotation range of the antenna to ± 90 degrees, 360 degrees and performs the sweeping procedure for each range of rotation until the received signal level L exceeds the threshold level Lb. If the received signal level L is decided as exceeding the threshold Lb at each of the steps 51 to 54, the microprocessor 1 stores the

information of the rotational direction of the antenna (step 55) and starts to execute the differentiation control.

Each of the steps 51 to 54 is expressed by a single step for convenience of explanation. However, each of those steps specifically has an array of units of three different steps each, arranged in each rotation direction. The number of units is equal to the ratio of (maximum rotation angle/unit rotation angle), and those three different steps are steps for rotating the antenna by a unit angle, steps for detecting the new received signal level and steps for comparing the received signal level L and the threshold Lb.

According to this embodiment, when the detected received signal level L is larger than the threshold Lb, the tracking azimuth is changed to increase the received signal level L. If the detected received signal level exceeds another threshold Lt which is larger than the threshold Lb and when the rate of change of the preceding tracking azimuth is smaller than a certain threshold, it is decided that the antenna body is substantially precisely directed toward the satellite, or in a good tracking state, and the tracking azimuth is maintained constant by the hold control. Thus, the wasteful tracking operation can be omitted by the addition of this hold control.

However, according to this tracking system for the radio wave from the satellite, when the received

signal level is suddenly decreased close to about noise level by the rapid increase of the tracking error due to a rapid turn of the mobile means, there is the fear that the tracking operation for the radio wave cannot be continued. Hereinafter, this situation is called "tracking-off". In this embodiment, when the received signal level L is reduced to be smaller than the threshold Lb, it is decided that this tracking-off is brought about. According to this embodiment, when this tracking-off occurs, a sweeping mode is added in which the satellite is searched for, while the antenna body is being turned with a vibrating movement, with its vibration amplitude gradually increased, about the tracking azimuth at which the antenna is directed when the tracking-off occurs.

The tracking-off is caused not only by the rapid turn of the mobile means but also when the mobile means enters in the shadow of an obstacle such as a mountain, tree or building even on a straight road. If this tracking-off is caused by an obstacle, the tracking azimuth of the antenna may be deviated far away from a proper value by the start of the sweeping mode. Thus, in this embodiment, an angular velocity sensor is provided, and the detected value therefrom and its integrated value are used to decide whether the tracking-off is caused by the rapid turn of the mobile means or by an obstacle.

According to the tracking system of this

embodiment, when the tracking-off is caused by the rapid turn of the vehicle, the sweeping mode is immediately started. However, in this sweeping mode, the tracking azimuth about which the antenna is turned with a vibrating movement may be largely deviated from a proper value as the mobile means rapidly turns. Therefore, if the time in which the antenna is again directed toward the satellite is tried to be reduced under the presence of such a large deviation, the antenna is required to turn faster over a large range of amplitude. As a result, it is necessary to provide a turning mechanism of which the structure is solid enough to endure a large load, but it becomes large-sized, weighty and expensive.

According to the differentiation control, the antenna is repeatedly turned over a certain range of angle. The antenna is got to be rotated at higher speed over this certain range of angle as the increment of the received signal level per unit angle relative to the preceding rotation becomes larger. In addition, as described above, if the received signal level is higher than the threshold Lt which is larger than the threshold Lb and if the preceding rotation velocity V of the antenna is smaller than a certain threshold Vth, the antenna is regarded as having been substantially precisely directed toward the satellite, or as being in a good tracking state, and the tracking azimuth is fixed by the hold control. In this hold control, the threshold Lt is defined as a ratio to the maximum

received signal level which is changed to a detected larger received signal level.

In the second embodiment of the invention, the sweeping mode in the first embodiment is replaced by a searching mode in which the satellite direction is presumed. In the second embodiment, the microprocessor 1 has a vehicle turning angle detection routine which is executed in a time-division way in parallel with the above radio-wave tracking control and a radio-wave tracking routine which is executed in parallel with the former routine. In the vehicle turning angle detection routine, the sampled values of angular velocity are successively read from the buffer memory of the input/output interface circuit 6 and integrated to produce the integrated value of the angular velocity, or the rotation angle of the vehicle. This value is written in an incorporated memory. In this vehicle turning angle detection routine, if the hold control is being executed in the radio-wave tracking routine which is performed in parallel with the vehicle turning angle detection routine, the detected turning angle of the vehicle is reset to zero.

In the vehicle turning angle detection routine, the search routine is started when a turning angle above a certain threshold is detected under the condition that the hold control is not made in the radio-wave tracking routine.

Fig. 7 shows the relation between the turning

angle of the mobile means and the tracking azimuth of the antenna. When the vehicle is turned by θ, the tracking azimuth of the antenna is also deviated by θ.

Fig. 8 is a waveform diagram of the angular velocity (A) which occurs when the vehicle is turned by θ and which is detected by the angular velocity meter 7, its integrated value (turning angle) (B), the center value (C) of the range of the tracking azimuth θ of the antenna body AT which is set by the search routine that is started under the tracking-off, the sweep angle amplitude (D) of the tracking azimuth range around the center of tracking angle, and the sweeping velocity (E) with respect to time. If a good tracking state is kept until the vehicle is started to turn, the microprocessor 1 is executing the hold control. In this hold control, the integrated value of the angular velocity detected by the angular velocity meter 7 is reset to zero with a certain period, and thus an accumulation error can be prevented from being caused by the error of the angular velocity meter 7.

When the vehicle starts to turn, the antenna is deviated out of the good tracking state at the direction indicated by a chain line with one dot. At this time, the radio-wave tracking operation according to the differentiation control is started in place of the hold control. After the start of the radio-wave tracking operation, the integrated value of the angular velocity (or the turning angle) is stopped from being

reset to zero and starts to increase. If the vehicle turns suddenly, the antenna cannot follow the radio wave from the satellite. At this time, if the received signal level is reduced below the threshold Lb, giving rise to the tracking-off, the search routine is started to execute in place of the radio-wave tracking routine. If this tracking-off is caused at the time indicated by the broken line in Fig. 8, the detected turning angle is θ_0 when the search routine starts.

When the search routine is started, the detected turning angle θ_0 is subtracted from the current tracking azimuth (0 degree), and the remainder ($-\theta_0$) is used as the center value of the sweeping range of the tracking azimuth. In addition, before or after this subtraction, a sweeping angular range $\Delta\theta i$ which stepwise increases, a sweeping velocity Vi and a sweeping time Ti are fixed. While the azimuth angle of the antenna is being stepwise changed around the set center value at the fixed sweeping velocity, over the fixed range and for the fixed time, repetitive decision is made of whether the received signal level L has exceeded the threshold Lb. During this sweeping operation, the center value of the range of the tracking azimuth is also repeatedly updated on the basis of the integrated value of the angular velocity produced after the start of the search routine. If it is decided that the received signal level L has exceeded the threshold Lb, the radio-wave tracking routine is resumed in place of

the search routine. If the received signal level is still smaller than the threshold Lb even after a predetermined time Tmax has elapsed from the start of the search routine, the final-stage search is started in which the antenna AT is rotated within an angular range up to 360 degrees.

Fig. 9 is a flowchart for one example of the search routine which the microprocessor 1 executes. When the search routine is started to execute, the microprocessor 1 resets the incorporated timer (step 61), and subtracts the detected turning angle θ_0 of the mobile means from the tracking azimuth at which the tracking-off occurs so that the remainder $-\theta_0$ is used as the center value of the sweeping range (step 62). Then, the microprocessor 1 decides whether the lapse time T from the start of the search operation has arrived at the time Tmax at which the final-stage search should be performed (step 63). If it is decided that the lapse time has not yet arrived, the microprocessor 1 sets, in addition to the lapse time T from the start of the search operation, the stepwise increasing sweep angular range $\Delta\theta i$, the sweeping velocity Vi and the sweeping time Ti (step 64).

Thereafter, the microprocessor 1 decides whether or not the received signal level L has exceeded the threshold Lb, while the angular range of $-\theta_0 \pm \Delta\theta i$ is swept at the velocity Vi (step 65, step 66). If the received signal level is smaller than the threshold Lb,

the microprocessor 1 subtracts the turning angle variation which the mobile means has caused after the setting of the center value from the center value $-\theta_0$ of the sweeping range which is being set, and sets the remainder as a new center value (step 67). Then, the microprocessor 1 decides whether or not the sweeping time has exceeded the time Ti (step 68). If the decision result is no, the routine goes back to step 65, and the microprocessor 1 repeats the step 65 to step 68. If the sweeping time has exceeded the set time Ti, the microprocessor 1 executes step 63 and step 64 where the sweeping angular range θi, sweeping velocity Vi and sweeping time Ti are once increased by a unit amount, and then it repeats the step 65 to step 68.

If deciding that the received signal level L has exceeded the threshold Lb at step 66, the microprocessor 1 stores the current tracking azimuth (step 70) and starts the radio-wave tracking mode of the differentiation control. If detecting that the lapse time T from the start of the search control has exceeded the certain time Tmax at step 63, the microprocessor 1 changes the tracking azimuth over an angular range of 360 degrees until the received signal level L exceeds the threshold Lb (step 69). If detecting that the received signal level L has exceeded the threshold Lb, the microprocessor 1 stores the tracking azimuth at which the received signal level has exceeded the threshold Lb (step 70), and again executes the

radio-wave tracking mode of the differentiation control. The step 69 is also executed immediately after the power supply for the satellite-broadcast receiving antenna apparatus is turned on.

This invention is not limited to the above embodiments. The above embodiments can be modified in various ways.

In the differentiation control, the rotation velocity is made proportional to the increment of the received signal level which occurs in the preceding rotation over a certain angle. However, the rotation velocity can be made proportional to the square of the increment or other proper functional relations can be established for the rotation velocity. Also, the increment of the received signal level over the above certain angle may be replaced by the increment per any arbitrary unit angle which is different from the above certain angle, for example, per 1° or per 10°.

The integrated value of the angular velocity is detected together with the angular velocity as described above, but it can be omitted depending on the kind of the mobile means and the detection precision of the angular velocity.

Only when it is decided that the tracking state by the radio-wave tracking means has been deviated out of the good tracking state, the integration of the stored angular velocity may be started a certain time early, so that it is possible to detect the turning

angle that the mobile means has turned immediately before the tracking-off.

In addition, the good tracking state may be detected only from the magnitude of the received signal level.

The turning angle of the mobile means before or after the tracking-off occurs may be detected by starting the integration from the point at which the angular velocity has exceeded a certain threshold.

When the tracking-off occurs under the condition that several most recent values are stored after periodically integrating the angular velocity irrespective of the received state, the amount of change of the integrated value stored immediately before that may be detected so that it is possible to detect the turning angle of the mobile means at which the tracking-off is caused.

After the start of satellite searching operation, the correction of the center value of the tracking azimuth range can be omitted in order that the time necessary for the integration can be reduced.

The sweeping amplitude angle and the sweeping velocity are not increased stepwise, but may be increased smoothly.

The pulse motor may be replaced by a combination of a DC motor and an encoder.

The single-axis tracking system for only the azimuth has been described above. However, if

necessary, the tracking operation for the elevation can also be made in the tracking control apparatus of the invention.

The tracking control apparatus of the invention is not limited to the satellite-broadcast receiving antenna, but can be applied to other antenna apparatus for receiving or transmitting a radio wave from or to another proper stationary satellite or moving satellite such as a communication satellite.

Moreover, the tracking control apparatus of the invention is not limited to the satellite-broadcast receiving antenna apparatus installed on a car, but can be applied to that installed on a vessel, a train or other mobile means.

INDUSTRIAL APPLICABILITY

As described in detail above, the tracking control apparatus of the invention has the differentiation control executing means which causes the satellite-broadcast receiving antenna to turn by a certain angle at a time at a higher rotation velocity as the increment of the received signal level per unit angle which is associated with the preceding rotation becomes larger. Therefore, a high tracking ability can be realized.

In addition, the tracking control apparatus of the invention detects the angular velocity and its integrated value at which the received signal level is

suddenly reduced, and immediately starts proper control according to whether this sudden reduction of the received signal level is caused by an obstacle or by rapid turning of the vehicle. Therefore, a further high tracking ability can be achieved.

Moreover, when the tracking-off occurs, the tracking control apparatus of the invention corrects the current tracking azimuth by use of the turning angle of the mobile means at which the tracking-off is caused, and causes the range of the tracking azimuth to be swept around this corrected value over an amplitude which is increased with lapse of time, so that the satellite is searched for. Therefore, the possibility that the center value of the sweeping range coincides with the direction of the satellite is higher than in the prior art in which such correction by the turning angle is not made. Thus, the time necessary for the direction of the satellite to be again caught under the low-speed and simple turning mechanism can be reduced as compared with the prior art.

Also, since the sweeping amplitude, preferably, the sweeping velocity can be gradually increased, the consumption power can be reduced together with the reduction of the time necessary for again catching the satellite.

Moreover, if the tracking-off is caused only by an obstacle while the mobile means is running on a straight road, the sweeping for searching is started to

be made around the current tracking azimuth since the turning angle of the mobile means is zero. Thus, it is possible to increase the possibility that the direction of the satellite can be again caught at the instant when the effect of the obstacle disappears.

Furthermore, even when the tracking-off is caused by simultaneous occurrence of an obstacle and turn of the mobile means, proper control can be made without discriminating the causes.

CLAIMS

1. A tracking control apparatus which is installed on a mobile means and controls a satellite-broadcast receiving antenna on the mobile means to receive a radio wave transmitted from a satellite, comprising tracking control means (20) for detecting the level of said radio wave received by said satellite-broadcast receiving antenna and controlling the rotation angle of said antenna on the basis of said detected received signal level, said tracking control means including differentiation control means (100) for repeatedly rotating said antenna over a certain angle at a higher rotation velocity as an increment of said received signal level per unit angle associated with the preceding rotation becomes large.

2. A tracking control apparatus according to claim 1, wherein said tracking control means (20) further includes hold control means (200) for holding the rotation angle of said antenna at a value at which said differentiation control is completely executed when said received signal level has exceeded a certain threshold (Lt), said hold control means being started to execute after said differentiation control means (100) is stopped from the execution when said received signal level exceeds said certain threshold (Lt) and when said rotation velocity is reduced down to a predetermined value.

3. A tracking control apparatus which is

installed on a mobile means and controls a satellite-broadcast receiving antenna on the mobile means to receive a radio wave transmitted from a satellite, comprising:

control means (100) for enhancing a tracking precision;

wait control means (300) for waiting for a received signal level to be restored over a certain period of time; and

tracking control means for detecting said received signal level of said radio wave which said antenna has received and an angular velocity of said mobile means and controlling the rotation angle of said antenna on the basis of said detected received signal level and acceleration, said tracking control means including hold control executing means (200) for comparing said received signal level with a first threshold (Lt), repeating the detection of a most-recent value of said received signal level and the comparison with said first threshold (Lt) while holding said rotation angle of said antenna at the current value if said received signal level exceeds said threshold, and for starting said control means (100) for enhancing the tracking precision if said angular velocity detected when said received signal level detected again is reduced to be lower than said first threshold (Lt) has exceeded a second threshold, or starting said wait control means (300) if said detected angular velocity is

lower than said second threshold.

4. A tracking control apparatus according to claim 3, wherein said hold control means (200) sets said first threshold (Lt) as a relative value to a peak value of said received signal level and changes said peak value of said received signal level to a detected most-recent value of said received signal level and said first threshold (Lt) to said most-recent peak value each time said most-recent value of said received signal level exceeds a larger threshold than its peak value multiplied by a magnification power.

5. A tracking control apparatus according to claim 3, wherein said control means (100) for enhancing the tracking precision makes differentiation control for repeatedly rotating said antenna over said certain angle at a higher rotation velocity as the increment of said received signal level per unit angle associated with the preceding rotation becomes larger.

6. A tracking control apparatus according to claim 5, wherein said control means (100) for enhancing the tracking precision is stopped from the execution when said received signal level exceeds said threshold Lt and when said rotation velocity is reduced to a predetermined value, and then causes said hold control means (200) to start.

7. A tracking control apparatus according to claim 3, wherein said tracking control means further has sweeping means (500) for rotating said antenna over a

maximum range of 360 degrees thereby searching for said satellite, said wait control means (300) includes a first portion for repeating at a high frequency the operation of detecting a most-recent value of said received signal level and of comparing said most-recent value with said threshold (Lt) and a second portion for repeating at a low frequency the operation of detecting a most-recent value of said received signal level and of comparing said most-recent value with said threshold (Lt), and causes said hold control means (200) to start if said received signal level is restored to a value exceeding said threshold (Lt) within said certain waiting period of time, and said sweeping means (500) to start if said received signal level is not restored to said value.

8. A tracking control apparatus according to claim 7, wherein said wait control means (300) is stopped from the execution when said angular velocity detected at a certain frequency within said waiting period exceeds a certain threshold, and then causes said control means (100) for enhancing the tracking precision to start.

9. A tracking control apparatus which is installed on a mobile means and controls a satellite-broadcast receiving antenna on the mobile means to receive a radio wave transmitted from a satellite, comprising:

control means (100) for enhancing the tracking

precision;

wait control means (300) for waiting for said received signal level to be restored over a certain period of time; and

tracking control means for detecting said received signal level of said radio wave which said antenna has received, an angular velocity of said mobile means and an integrated value of said angular velocity and for controlling the rotation angle of said antenna on the basis of said detected received signal level, angular velocity and integrated value of said angular velocity, said tracking control means including hold control means (200) for comparing said received signal level with a certain threshold (Lt), repeating the detection of a most-recent value of said received signal level and comparison with said threshold (Lt) while holding the rotation angle of said antenna at the current value if said received signal level exceeds said threshold, and for starting said control means (100) for enhancing the tracking precision if either one of said angular velocity detected when said received signal level detected again is reduced to be smaller than said threshold (Lt) and an integrated value of said angular velocity is larger than the corresponding one of thresholds provided for said angular velocity and said integrated value, or starting said wait control means (300) if said detected angular velocity and said integrated value are both lower than said threshold.

10. A tracking control apparatus according to claim 9, wherein said hold control means (200) sets said threshold Lt as a relative value to a peak value of said received signal level, and changes said peak value of said received signal level to said most-recent value of said received signal level and said threshold (Lt) to said most-recent peak each time said detected most-recent value of said received signal level exceeds a threshold that is larger than said peak value multiplied by a certain magnification power.

11. A tracking control apparatus according to claim 9, wherein said control means (100) for enhancing the tracking precision makes differentiation control for repeatedly rotating said antenna over said certain angle at a higher rotation velocity as the increment of said received signal level per unit angle associated with the preceding rotation becomes larger.

12. A tracking control apparatus according to claim 11, wherein said control means 100 for enhancing the tracking precision is stopped from being executed when said received signal level exceeds said threshold (Lt) and when said rotation velocity is reduced below a predetermined value, and causes said hold control means (200) to start.

13. A tracking control apparatus according to claim 9, wherein said tracking control means further has sweeping means (500) for rotating said antenna with a maximum range up to 360 degrees to thereby search for

said satellite, and said wait control means (300) has a first portion for repeating at a high frequency the operation of detecting a most-recent value of said received signal level and of comparing said detected value with said threshold (Lt), and a second portion for repeating at a low frequency the operation of detecting a most-recent value of said received signal level and of comparing said detected value with said threshold (Lt), and causes said hold control means (200) to start if said received signal level is restored to a value exceeding said threshold (Lt) within said waiting period, and said sweeping means (500) to start if said received signal level is not restored.

14. A tracking control apparatus according to claim 13, wherein said wait control means (300) is stopped from being executed when said angular velocity detected at a certain frequency within said waiting period exceeds a certain threshold, and causes said control means (100) for enhancing the tracking precision to start.

15. A tracking control apparatus according to claim 13, wherein said waiting control means (300) is stopped from being executed when said received signal level detected within said waiting period appears a certain number of times successively between said threshold (Lt) and a lower threshold (Lm) than that, and causes said control means (100) for enhancing the tracking precision to start.

16. A tracking control apparatus according to claim 9, wherein said satellite is a broadcasting satellite on a stationary orbit and said mobile means is a vehicle.

17. A mobile-type satellite-broadcast receiving antenna apparatus installed on a mobile means and having an antenna (AT) for receiving a radio wave transmitted from a satellite and an automatic tracking portion (20) for changing at least the horizontal component (hereinafter, referred as "tracking azimuth") of the direction of said antenna to thereby direct said antenna toward said satellite, wherein said automatic tracking portion (20) comprises:

received-level detecting means (5) for detecting a received signal level of said radio wave which said antenna (AT) has received;

angular velocity detecting means (17) for detecting the horizontal component of an angular velocity of said mobile means upon turning;

radio-wave tracking means (1) for changing said tracking azimuth to increase said detected received signal level when said detected received signal level exceeds a certain threshold;

turning-angle detecting means (1) for detecting a turning angle of said mobile means by integrating the horizontal component of said angular velocity which said angular velocity detecting means has detected; and

satellite searching means (1) for detecting, when said received signal level which said received-level detecting means has detected is reduced to be less than said threshold, an amount of change of said turning angle which said turning-angle detecting means has detected immediately before the reduction of said received signal level, correcting a current tracking azimuth on the basis of said amount of change of said turning angle, and changing said tracking azimuth around said corrected value over an amplitude which is increased with lapse of time, thereby making a search for said satellite.

18. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said turning-angle detecting means (1) starts integrating the horizontal component of said detected angular velocity from the time point when the tracking state which said radio-wave tracking means makes is decided to have deviated out of a good tracking state which has a small tracking error.

19. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said turning-angle detecting means (1) detects the turning angle of said mobile means by integrating the horizontal component of said detected angular velocity, and sets said detected value as a predetermined reference value when the tracking state which said radio-wave tracking means makes is decided to be said good tracking state

which has a small tracking error.

20. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 18, wherein:

said radio-wave tracking means (1) has hold control means (200) for stopping said tracking azimuth from being changed when said detected received signal level exceeds a second threshold which is larger than said threshold and when the preceding velocity of the change of said tracking azimuth is lower than a certain threshold; and

said turning-angle detecting means (1) decides said good tracking state when said radio-wave tracking means (1) is in a hold control state.

21. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 20, wherein said second threshold is defined as a ratio to a maximum received signal level which is changed to a detected larger received signal level.

22. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said turning-angle detecting means (1) starts said integration when said angular velocity which said angular velocity detecting means (7) has detected exceeds a certain threshold.

23. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said satellite searching means (1) corrects the center value around which said tracking azimuth is changed on the

basis of the turning angle of said mobile means which turns after the search for said satellite is started.

24. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 22, wherein said satellite searching means (1) corrects the center value around which said tracking azimuth is changed on the basis of the turning angle of said mobile means which turns after the search for said satellite is started.

25. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said satellite searching means (1) changes said tracking azimuth at a velocity which is increased with lapse of time.

26. A mobile-type satellite-broadcast receiving antenna apparatus according to claim 17, wherein said radio-wave tracking means (1) changes said tracking azimuth over a certain range at higher velocity as the increment of said received signal level per unit angle associated with the preceding change becomes larger.

FIG. 1

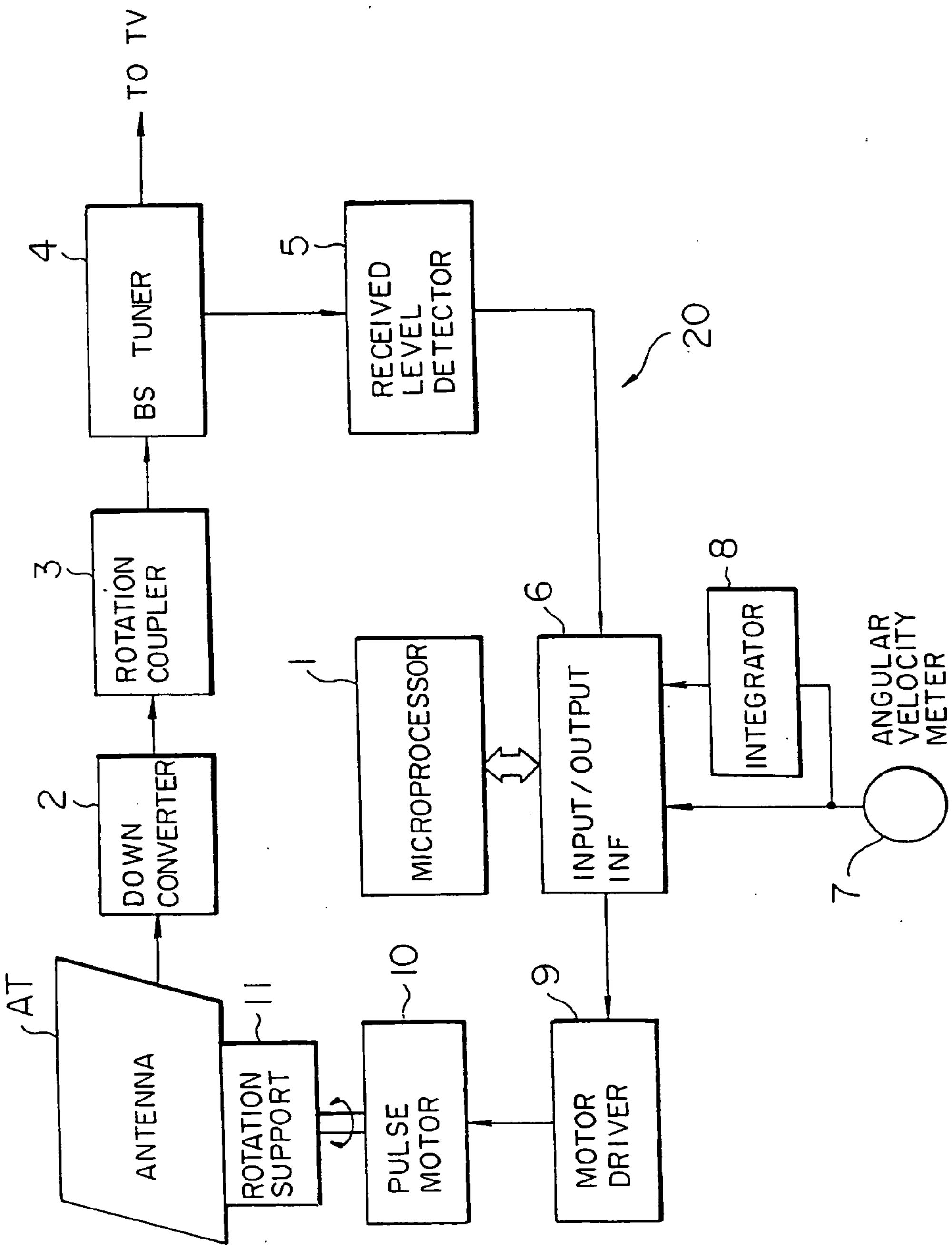

TO TV
4
BS TUNER
5
RECEIVED LEVEL DETECTOR
20
3
ROTATION COUPLER
2
DOWN CONVERTER
1
MICROPROCESSOR
6
INPUT / OUTPUT INF
8
INTEGRATOR
ANGULAR VELOCITY METER
7
AT
ANTENNA
11
ROTATION SUPPORT
10
PULSE MOTOR
9
MOTOR DRIVER

FIG. 2

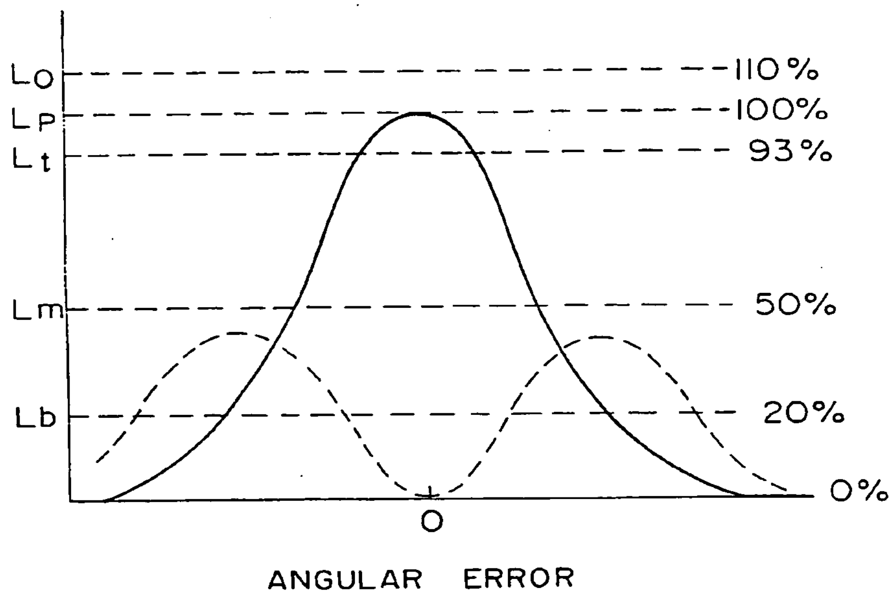


FIG.3

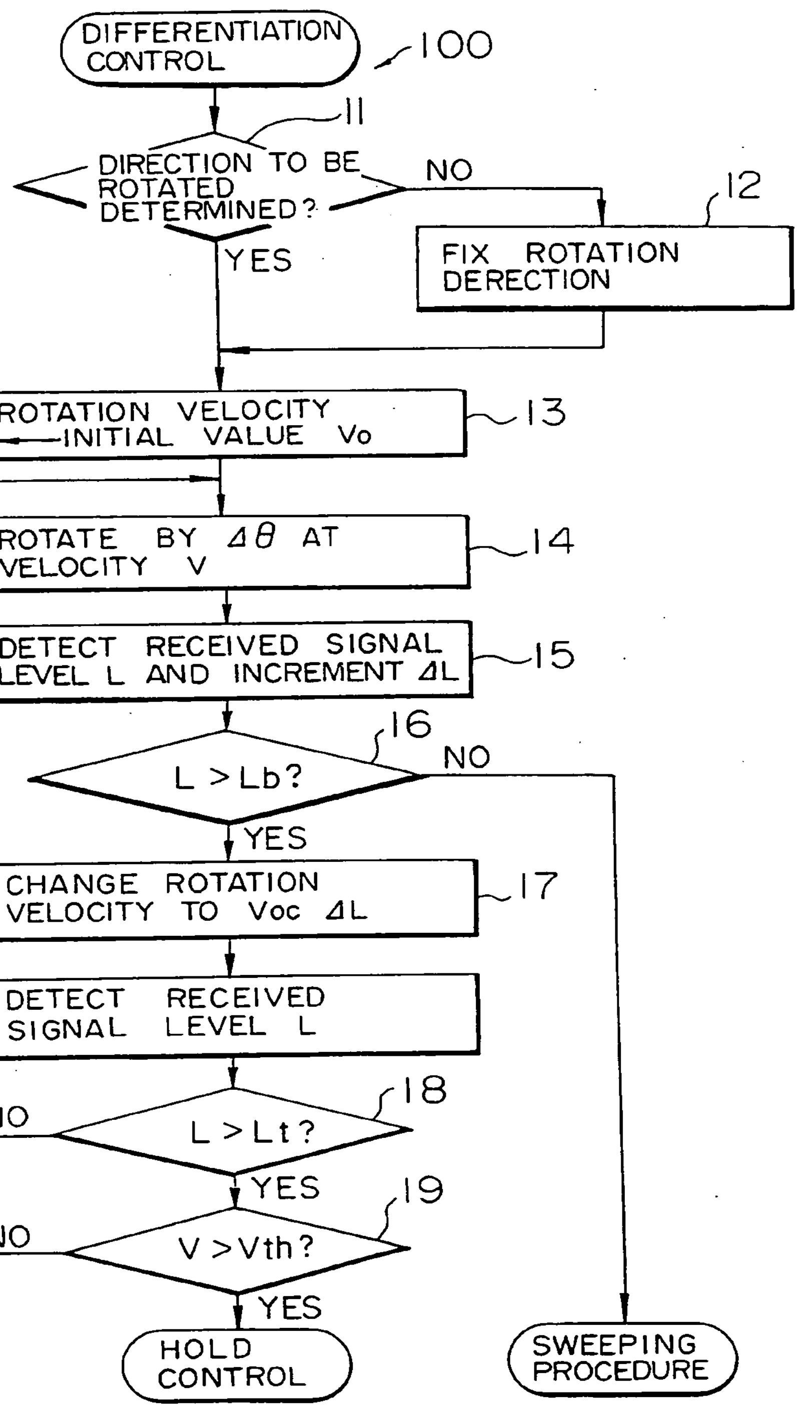

DIFFERENTIATION CONTROL
100
11
DIRECTION TO BE ROTATED DETERMINED?
NO
YES
12
FIX ROTATION DERECTION
ROTATION VELOCITY ←INITIAL VALUE Vo
13
ROTATE BY Δθ AT VELOCITY V
14
DETECT RECEIVED SIGNAL LEVEL L AND INCREMENT ΔL
15
16
L > Lb?
NO
YES
CHANGE ROTATION VELOCITY TO Voc ΔL
17
DETECT RECEIVED SIGNAL LEVEL L
18
NO
L > Lt?
YES
19
NO
V > Vth?
YES
HOLD CONTROL
SWEEPING PROCEDURE

FIG. 4

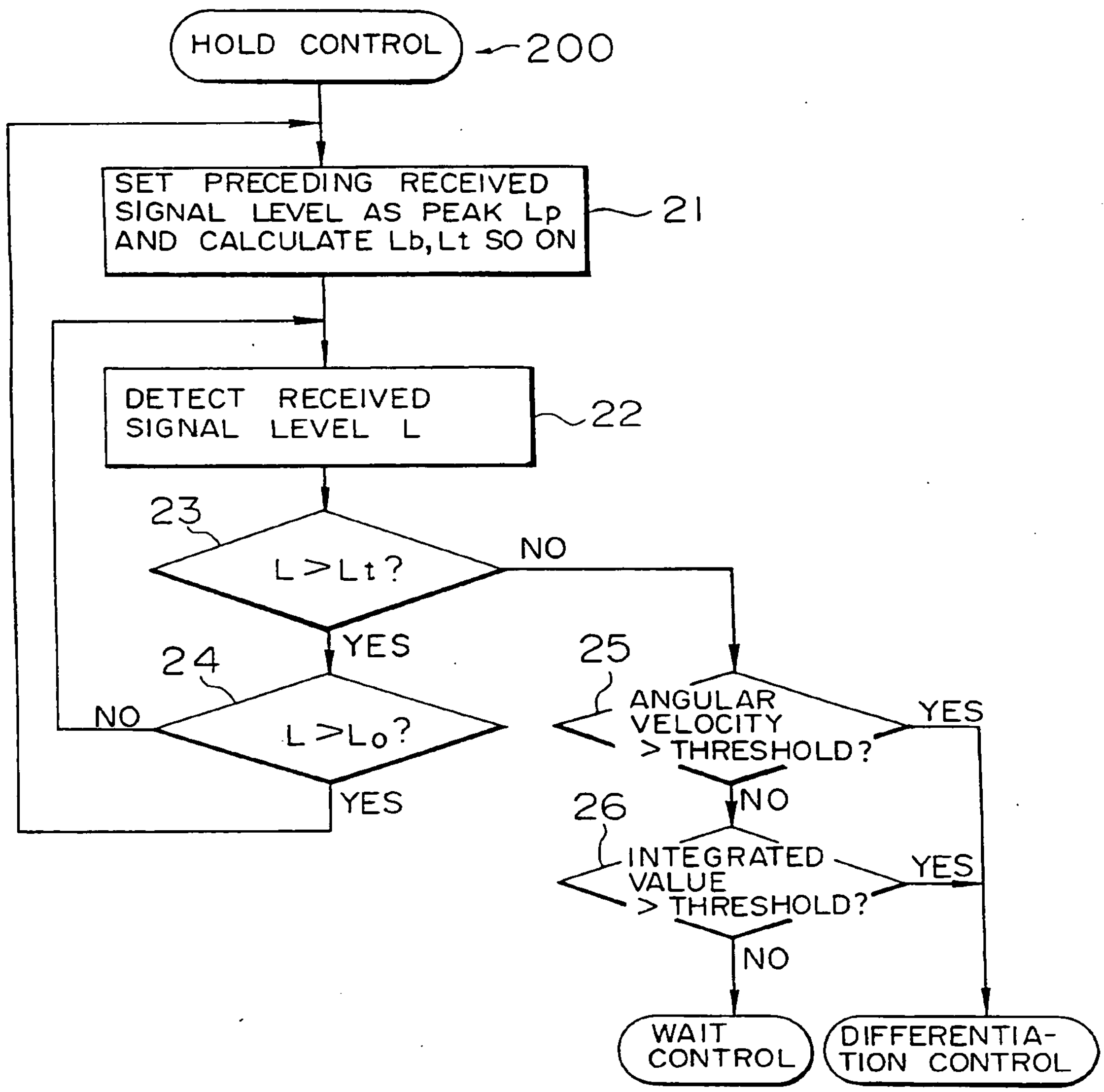

HOLD CONTROL
200
SET PRECEDING RECEIVED SIGNAL LEVEL AS PEAK Lp AND CALCULATE Lb, Lt SO ON
21
DETECT RECEIVED SIGNAL LEVEL L
22
23
L>Lt?
NO
YES
24
NO
L>Lo?
YES
25
ANGULAR VELOCITY > THRESHOLD?
YES
NO
26
INTEGRATED VALUE > THRESHOLD?
YES
NO
WAIT CONTROL
DIFFERENTIA-TION CONTROL

FIG. 5

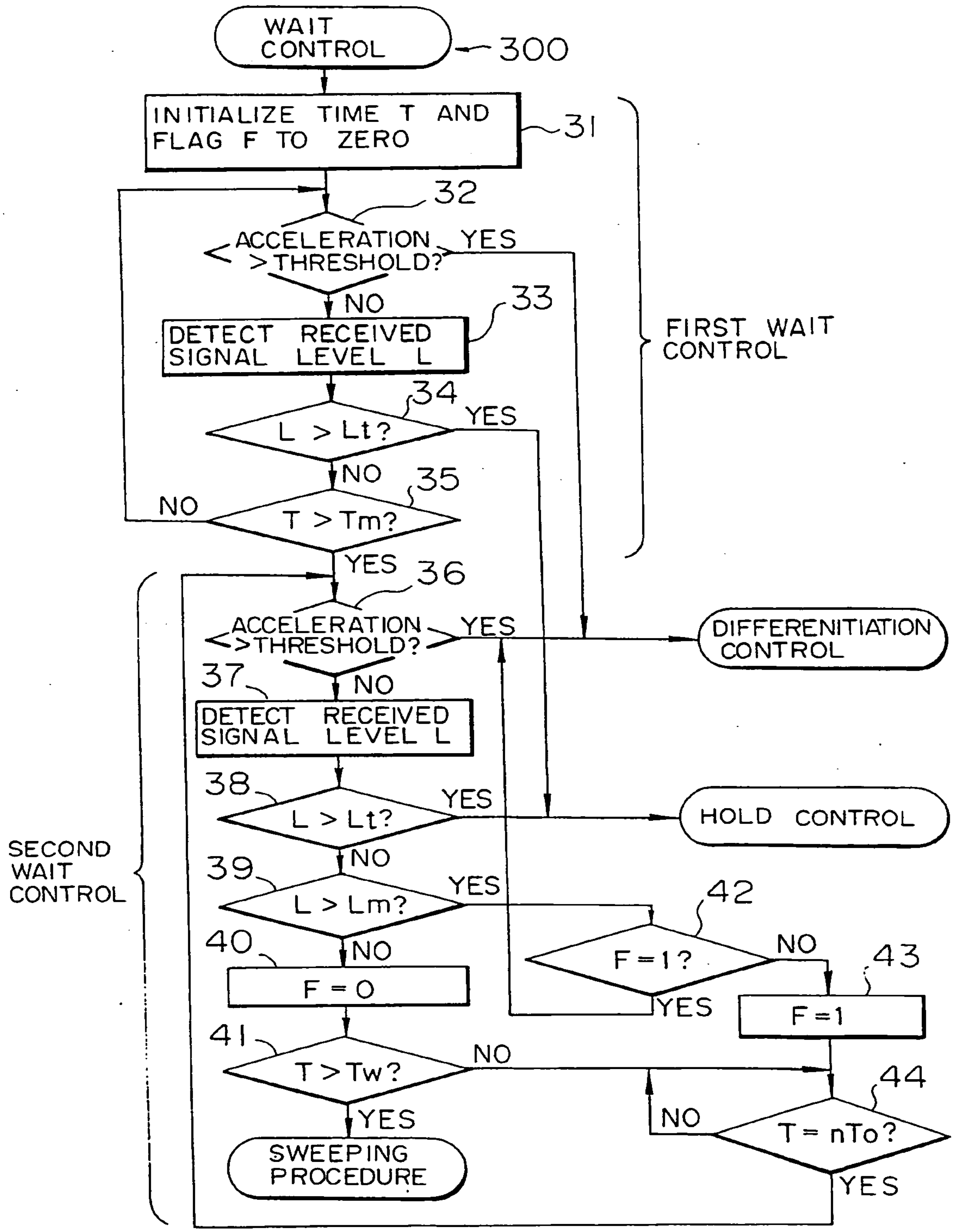

WAIT CONTROL
300
INITIALIZE TIME T AND FLAG F TO ZERO
31
32
ACCELERATION >THRESHOLD?
YES
NO
33
DETECT RECEIVED SIGNAL LEVEL L
FIRST WAIT CONTROL
34
L > Lt?
YES
NO
35
NO
T > Tm?
YES
36
ACCELERATION >THRESHOLD?
YES
DIFFERENITIATION CONTROL
37
NO
DETECT RECEIVED SIGNAL LEVEL L
38
L > Lt?
YES
HOLD CONTROL
NO
39
L > Lm?
YES
42
SECOND WAIT CONTROL
40
NO
F=1?
NO
43
F = 0
YES
F = 1
41
T > Tw?
NO
44
NO
T = nTo?
YES
SWEEPING PROCEDURE
YES

FIG. 6

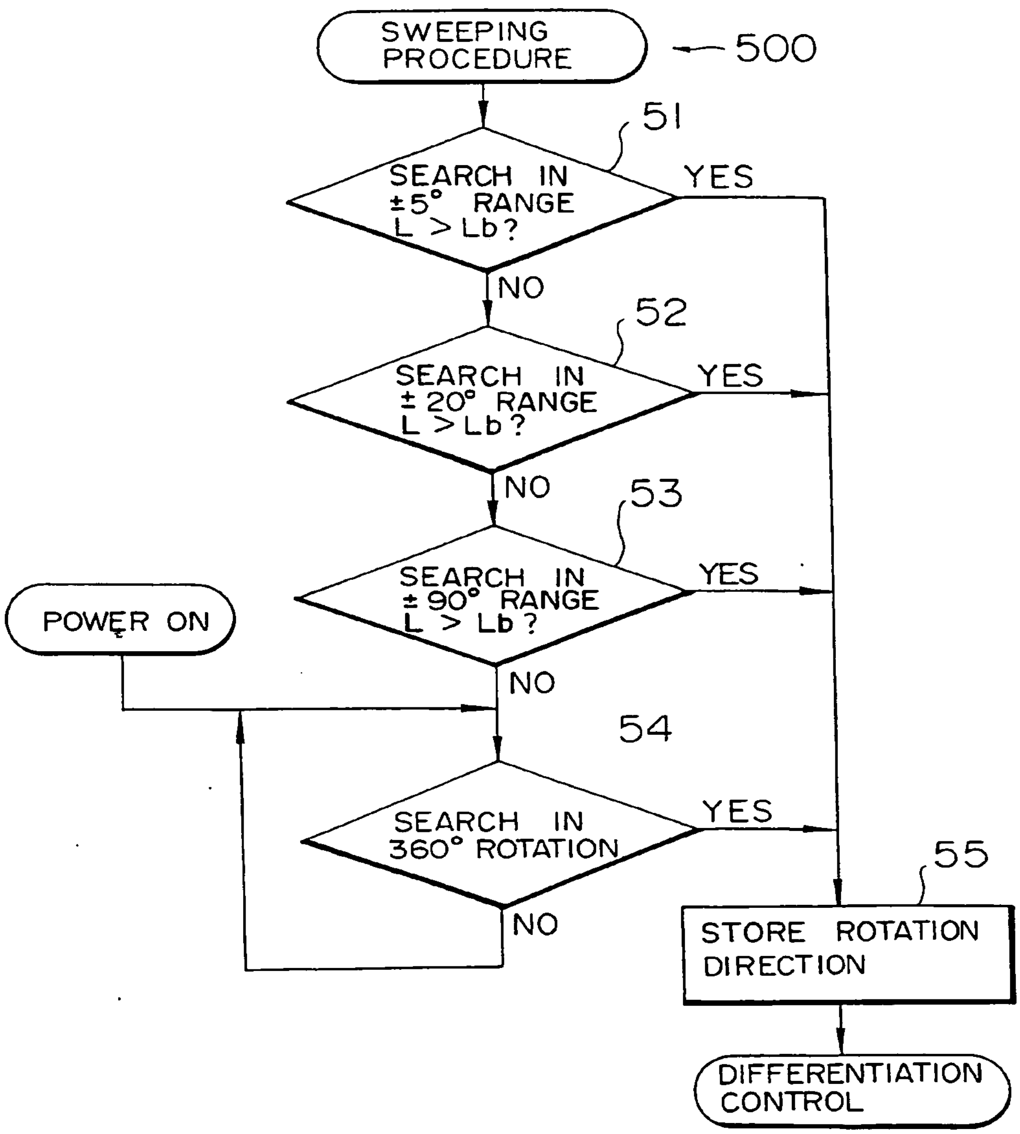

SWEEPING PROCEDURE
500
51
SEARCH IN ±5° RANGE L > Lb?
YES
NO
52
SEARCH IN ± 20° RANGE L > Lb?
YES
NO
53
SEARCH IN ± 90° RANGE L > Lb?
YES
POWER ON
NO
54
SEARCH IN 360° ROTATION
YES
NO
55
STORE ROTATION DIRECTION
DIFFERENTIATION CONTROL

FIG. 7

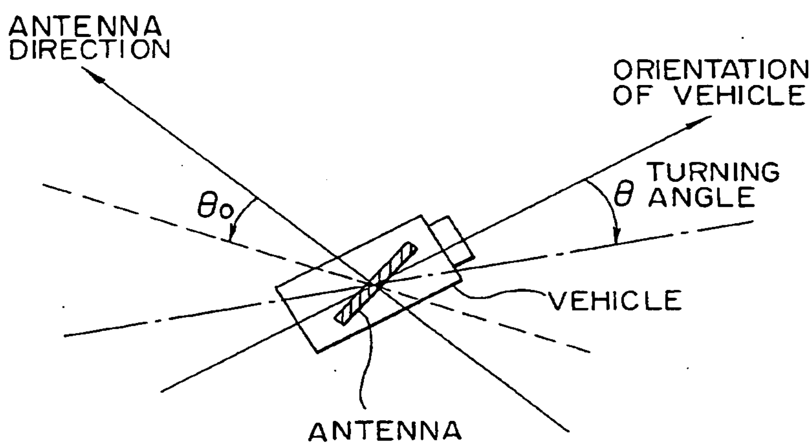

ANTENNA DIRECTION
ORIENTATION OF VEHICLE
TURNING ANGLE
θ
θ_0
VEHICLE
ANTENNA

FIG. 8

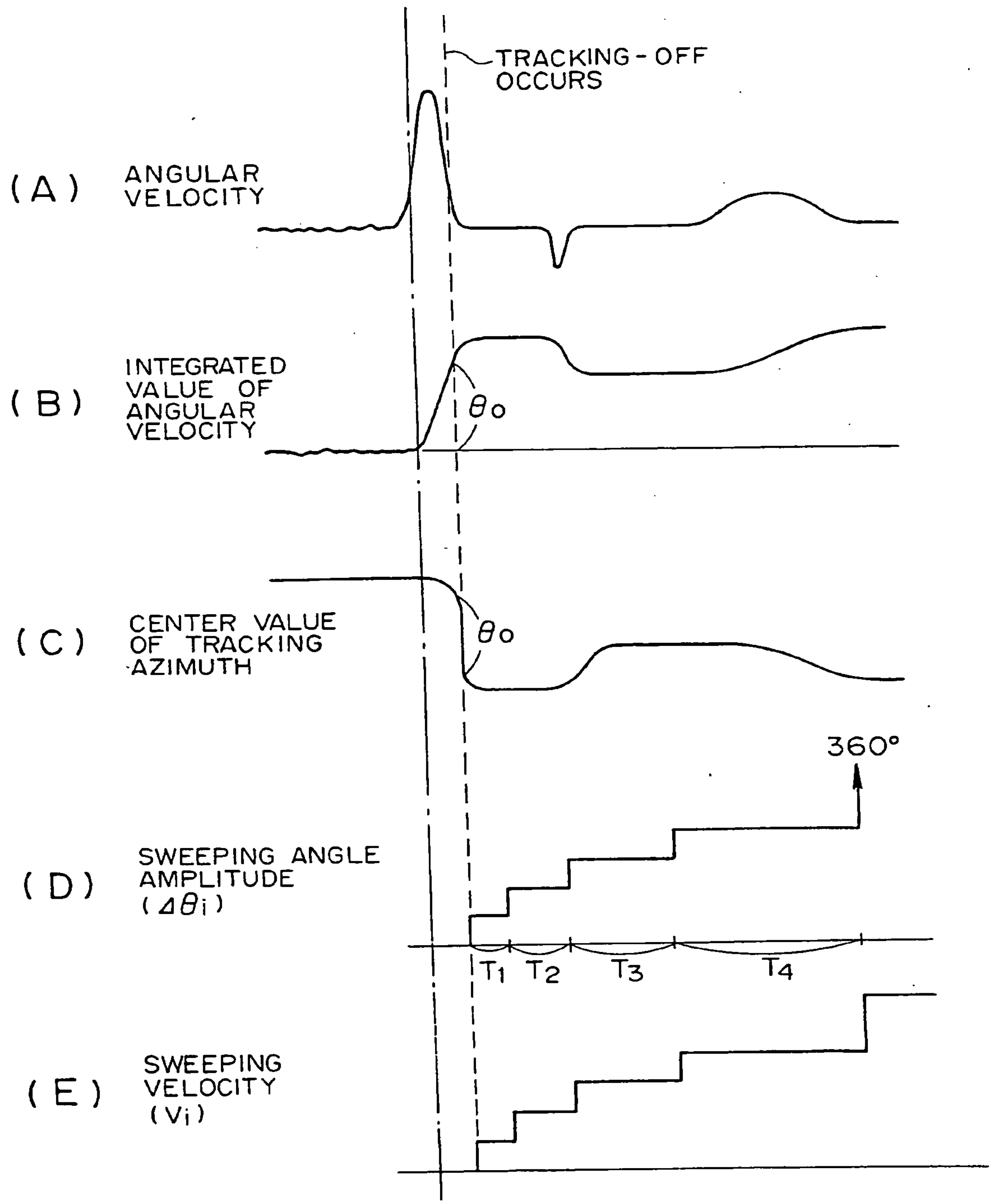
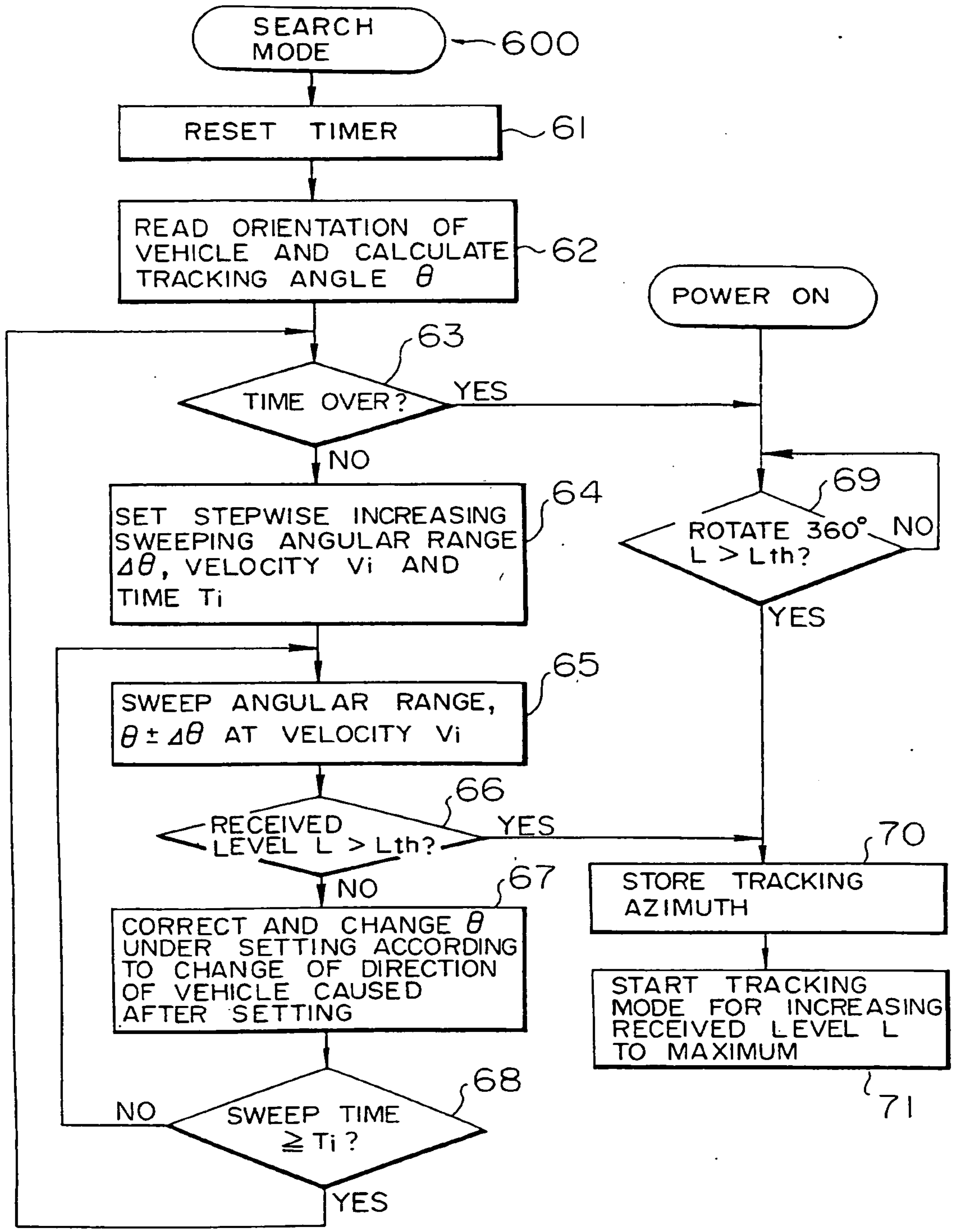

TRACKING - OFF OCCURS
(A) ANGULAR VELOCITY
(B) INTEGRATED VALUE OF ANGULAR VELOCITY
θo
(C) CENTER VALUE OF TRACKING AZIMUTH
θo
360°
(D) SWEEPING ANGLE AMPLITUDE (Δθi)
T1 T2 T3 T4
(E) SWEEPING VELOCITY (Vi)

FIG. 9


SEARCH MODE
600
RESET TIMER
61
READ ORIENTATION OF VEHICLE AND CALCULATE TRACKING ANGLE θ
62
POWER ON
63
TIME OVER?
YES
NO
SET STEPWISE INCREASING SWEEPING ANGULAR RANGE Δθ, VELOCITY Vi AND TIME Ti
64
69
ROTATE 360° L > Lth?
NO
YES
SWEEP ANGULAR RANGE, θ ± Δθ AT VELOCITY Vi
65
66
RECEIVED LEVEL L > Lth?
YES
70
NO
STORE TRACKING AZIMUTH
67
CORRECT AND CHANGE θ UNDER SETTING ACCORDING TO CHANGE OF DIRECTION OF VEHICLE CAUSED AFTER SETTING
START TRACKING MODE FOR INCREASING RECEIVED LEVEL L TO MAXIMUM
71
68
NO
SWEEP TIME ≧ Ti ?
YES

INTERNATIONAL SEARCH REPORT

Intern. al Application No
PCT/JP 95/00047

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01Q1/32 H01Q3/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 452 970 (NEC) 23 October 1991 see claims 1-3; figures 1-6 ---	1-26
A	US,A,5 274 382 (WILLS ET AL.) 28 December 1993 see column 2, line 30 - column 3, line 16; figure 1 ---	1,3,9,17
A	US,A,5 245 348 (NISHIKAWA ET AL.) 14 September 1993 see column 2, line 6 - column 3, line 32; figures 1-11 -----	1,3,9,17

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 1995	02.05.95

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/JP 95/00047

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
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		AU-B-	648548	28-04-94
		AU-A-	7519591	24-10-91
		US-A-	5241319	31-08-93
US-A-5274382	28-12-93	NONE		
US-A-5245348	14-09-93	JP-A-	4273082	29-09-92
		AU-B-	644946	23-12-93
		AU-A-	1129292	03-09-92

Form PCT/ISA/210 (patent family annex) (July 1992)